PB82-232687

National Air Pollutant Emission Estimates 1970-1978

(U.S.) Environmental Protection Agency
Research Triangle Park, NC

Nov 79

U.S. Department of Commerce
National Technical Information Service
NTIS

United States
Environmental Protection
Agency

Office of Air Quality
Planning and Standards
Research Triangle Park NC 27711

EPA-450/4-80-002
January 1980

Air

PB82-232687

EPA

National Air Pollutant Emission Estimates, 1970 — 1978

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U.S. DEPARTMENT OF COMMERCE
SPRINGFIELD, VA. 22161

TECHNICAL REPORT DATA
(Please read Instructions on the reverse before completing)

1. REPORT NO. EPA-450/4-80-002	2.
3. RECIPIENT'S ACCESSION NO. PB82-232687	
4. TITLE AND SUBTITLE: National Air Pollutant Emission Estimates, 1970-1978	5. REPORT DATE: November 1979
	6. PERFORMING ORGANIZATION CODE
7. AUTHOR(S): Monitoring and Data Analysis Division	8. PERFORMING ORGANIZATION REPORT NO.
9. PERFORMING ORGANIZATION NAME AND ADDRESS: U.S. Environmental Protection Agency, Office of Air, Noise and Radiation, Office of Air Quality Planning and Standards, Research Triangle Park, North Carolina 27711	10. PROGRAM ELEMENT NO.
	11. CONTRACT/GRANT NO.
12. SPONSORING AGENCY NAME AND ADDRESS: U.S. Environmental Protection Agency, Office of Air Quality Planning and Standards, Monitoring and Data Analysis Division, Research Triangle Park, North Carolina 27711	13. TYPE OF REPORT AND PERIOD COVERED: Final
	14. SPONSORING AGENCY CODE
15. SUPPLEMENTARY NOTES	

16. ABSTRACT

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17. KEY WORDS AND DOCUMENT ANALYSIS

a. DESCRIPTORS	b. IDENTIFIERS/OPEN ENDED TERMS	c. COSATI Field/Group
trends, emissions, inventory, air pollutants, nationwide, sulfur oxides, carbon monoxide, particulates, hydrocarbons, nitrogen oxides, controllable emissions, miscellaneous sources		

18. DISTRIBUTION STATEMENT: Release unlimited	19. SECURITY CLASS *(This Report)*: Unclassified	21. NO. OF PAGES: 43
	20. SECURITY CLASS *(This page)*: Unclassified	22. PRICE

EPA Form 2220-1 (9-73)

EPA-450/4-80-002

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Monitoring and Data Analysis Division

U.S. ENVIRONMENTAL PROTECTION AGENCY
Office of Air, Noise, and Radiation
Office of Air Quality Planning and Standards
Research Triangle Park, North Carolina 27711

January 1980

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Publication No. EPA-450/4-80-002

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This report presents estimates of trends in nationwide air pollutant emissions for the five major pollutants: particulates, sulfur oxides, nitrogen oxides, volatile organic compounds, and carbon monoxide. Estimates are presented for each year from 1970 through 1978. Emission estimates are broken down according to major classifications of air pollution sources. A short analysis of trends is given, along with a discussion of methods used to develop the data.

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NATIONAL AIR POLLUTANT EMISSION ESTIMATES

1970-1978

1. SUMMARY

Table 1 summarizes estimated national emissions for each year. As shown in the table, estimated particulate emissions (TSP) have decreased substantially, emissions of sulfur oxides (SOx), volatile organic compounds (VOC), and carbon monoxide (CO) have declined slightly, while nitrogen oxide emissions (NOx) have increased.

These data entirely replace those published earlier for 1970-1976 in EPA reports National Air Quality and Emissions Trends Report, 1976 (EPA-450/1-77-002) and National Air Pollutant Emissions Estimates 1940-1976 (EPA-450/1-78-003) and for 1970-1977 in the National Air Quality, Monitoring, and Emissions Trends Report, 1977 (EPA-450/2-78-052). Because of modifications in methodology and use of more refined emission factors, data from this report should not be compared with data in these earlier reports.

Reporting of emissions on a nationwide basis, while useful as a general indicator of pollutant levels, has definite limitations. National totals or averages are not the best guide for estimating trends for particular localities. Yet, it is important that some criteria be established for measurement of national progress in the control of air pollutant emissions. The emission estimates presented herein represent calculated estimates based on standard emission inventory procedures. Since these data are estimates only and do not represent the results of any program for the measurement of actual emissions, their accuracy is somewhat limited. Similarly, it would not necessarily be expected that these emission estimates would be in agreement with emission estimates derived through a different emission inventory procedure. The principal objective of compiling these data is to identify probable overall changes in emissions on a national scale. It should be recognized that these estimated national trends in emissions may not be representative of local trends in emissions or air quality.

TABLE 1

SUMMARY OF NATIONAL EMISSION ESTIMATES

TERAGRAMS/YEAR

Year	TSP	SOX	NOX	VOC	CO
1970	23.2	29.8	19.9	28.3	102.6
1971	22.0	28.2	20.6	27.8	103.1
1972	21.0	29.3	21.6	28.3	104.4
1973	20.3	30.4	22.4	28.4	103.5
1974	17.9	28.5	21.8	27.1	99.6
1975	14.6	26.2	20.9	25.3	97.2
1976	14.1	27.4	22.5	27.0	102.9
1977	13.6	27.2	23.4	27.1	102.4
1978	12.5	27.0	23.3	27.8	102.1
Change 1970-1978	-46.1%	-9.4%	+17.1%	-1.8%	-0.5%

Note: One teragram equals 10^{12} grams (10^6 metric tons) or approximately 1.1×10^6 short tons.

2. NATIONWIDE EMISSION TRENDS, 1970-1978

Tables 2 through 6 show trends in the emissions of each pollutant according to major source categories. More detailed breakdowns of the emissions from highway vehicles are given in Tables 7 through 9, for stationary source fuel combustion in Tables 10 through 12, and for industrial processes in Tables 13 through 17.

2.1 Particulates

Particulate emissions result primarily from fuel combustion in stationary sources and from industrial processes. From 1970 through 1978, total particulate emissions have decreased by 46 percent. This substantial decrease is due primarily to installation of control equipment on industrial processes and coal-fired stationary fuel combustion sources. In addition, particulate emissions have decreased because of less burning of solid waste.

2.2 Sulfur Oxides

Sulfur oxide emissions occur mostly from stationary source fuel combustion. In addition, sulfur oxide emissions from industrial processes are significant. From 1970 to 1978, emissions of sulfur oxides decreased by 9 percent. This decrease relates directly to decreased emissions from primary nonferrous smelters and sulfuric acid manufacturing plants. Emissions from other sources have not changed significantly.

2.3 Nitrogen Oxides

Emissions of nitrogen oxides are produced almost entirely by fuel combustion by stationary sources and transportation sources. Nitrogen oxide emissions increased about 17 percent from 1970 to 1978. This increase is due to increased motor vehicle travel and increased fuel use by electric utilities.

2.4 Volatile Organic Compounds

Volatile organic compound emissions decreased slightly, by about 2 percent. As a result of the Federal motor vehicle control program, emissions from highway vehicles decreased by 10 percent. In addition, emissions from miscellaneous organic solvent use decreased, mainly due to the substitution of water-based emulsified asphalts for those liquified with petroleum distillates. However,

emissions from industrial processes increased. This increase partially offsets the decreases in emissions for other source categories, resulting in an overall minor change in total emissions.

2.5 Carbon Monoxide

Carbon monoxide emissions occur largely from transportation sources. Despite the Federal motor vehicle control program, emissions from highway vehicles increased by 9 percent from 1970 to 1978. For other source categories, no significant change occurred except for emissions from burning of solid waste and agricultural materials, which are estimated to have decreased substantially. The overall effect of these changes is that total CO emissions decreased from 1973 to 1975, but then increased again by 1978 to approximately the same level as 1970 emissions.

TABLE 2

NATIONAL ESTIMATES OF PARTICULATE EMISSIONS

TERAGRAMS/YEAR

SOURCE CATEGORY	1970	1971	1972	1973	1974	1975	1976	1977	1978
Transportation									
Highway vehicles	0.7	0.7	0.8	0.8	0.8	0.7	0.8	0.8	0.9
Aircraft	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1
Railroads	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1
Vessels	0.1	0.1	0.1	0.1	0.1	0.0	0.0	0.0	0.0
Other motor vehicles	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.2	0.2
Transportation Total	1.1	1.1	1.2	1.2	1.2	1.0	1.0	1.2	1.3
Fuel combustion in stationary sources	7.2	6.6	6.6	6.6	5.6	5.1	4.7	4.8	3.8
Industrial processes	12.8	12.3	11.6	11.2	9.8	7.4	7.0	6.4	6.2
Solid waste disposal									
Muncipial incineration	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1
Other incineration	0.3	0.3	0.2	0.2	0.2	0.2	0.2	0.2	0.2
Open burning	0.7	0.5	0.4	0.3	0.3	0.2	0.2	0.2	0.2
Solid Waste Total	1.1	0.9	0.7	0.6	0.6	0.5	0.5	0.5	0.5
Miscellaneous									
Forest fires	0.5	0.7	0.5	0.5	0.5	0.4	0.6	0.5	0.5
Agricultural burning	0.3	0.2	0.2	0.1	0.1	0.1	0.1	0.1	0.1
Coal refuse burning	0.1	0.1	0.1	0.0	0.0	0.0	0.0	0.0	0.0
Structural fires	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1
Misc. organic solvent	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Miscellaneous Total	1.0	1.1	0.9	0.7	0.7	0.6	0.8	0.7	0.7
Total	23.2	22.0	21.0	20.3	17.9	14.6	14.1	13.6	12.5

TABLE 3

NATIONAL ESTIMATES OF SULFUR OXIDE EMISSIONS

TERAGRAMS/YEAR

SOURCE CATEGORY	1970	1971	1972	1973	1974	1975	1976	1977	1978
Transportation									
Highway vehicles	0.3	0.3	0.3	0.3	0.4	0.4	0.4	0.4	0.4
Aircraft	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Railroads	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1
Vessels	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2
Other motor vehicles	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1
Transportation Total	0.7	0.7	0.7	0.7	0.8	0.8	0.8	0.8	0.8
Fuel combustion in stationary sources	22.7	21.6	22.1	23.2	22.1	20.9	22.2	22.2	22.1
Industrial processes	6.2	5.7	6.3	6.3	5.5	4.5	4.4	4.2	4.1
Solid waste disposal									
Municipal incineration	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Other incineration	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Open burning	0.1	0.1	0.1	0.1	0.1	0.0	0.0	0.0	0.0
Solid Waste Total	0.1	0.1	0.1	0.1	0.1	0.0	0.0	0.0	0.0
Miscellaneous									
Forest fires	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Agricultural burning	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Coal refuse burning	0.1	0.1	0.1	0.1	0.0	0.0	0.0	0.0	0.0
Structural fires	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Misc. organic solvent	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Miscellaneous Total	0.1	0.1	0.1	0.1	0.0	0.0	0.0	0.0	0.0
Grand Total	29.8	28.2	29.3	30.4	28.5	26.2	27.4	27.2	27.0

TABLE 4

NATIONAL ESTIMATES OF NITROGEN OXIDE EMISSIONS

TERAGRAMS/YEAR

SOURCE CATEGORY	1970	1971	1972	1973	1974	1975	1976	1977	1978
Transportation									
Highway vehicles	5.3	5.8	6.3	6.5	6.4	6.4	6.6	6.8	6.7
Aircraft	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1
Railroads	0.6	0.6	0.7	0.7	0.7	0.6	0.7	0.7	0.7
Vessels	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.2	0.2
Other motor vehicles	1.3	1.3	1.4	1.5	1.4	1.4	1.5	1.6	1.7
Transportation Total	7.4	7.9	8.6	8.9	8.7	8.6	9.0	9.4	9.4
Fuel combustion in stationary sources	11.3	11.5	11.9	12.4	12.1	11.3	12.5	13.0	12.9
Industrial processes	0.7	0.7	0.8	0.8	0.7	0.7	0.7	0.8	0.8
Solid waste disposal									
Municipal incineration	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Other incineration	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Open burning	0.3	0.3	0.2	0.2	0.2	0.2	0.1	0.1	0.1
Solid Waste Total	0.3	0.3	0.2	0.2	0.2	0.2	0.1	0.1	0.1
Miscellaneous									
Forest fires	0.4	0.2	0.1	0.1	0.1	0.1	0.2	0.1	0.1
Agricultural burning	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Coal refuse burning	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Structural fires	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Misc. organic solvent	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Miscellaneous Total	0.2	0.2	0.1	0.1	0.1	0.1	0.2	0.1	0.1
Grand Total	19.9	20.6	21.6	22.4	21.8	20.9	22.5	23.4	23.3

TABLE 5

NATIONAL ESTIMATES OF VOLATILE ORGANIC COMPOUND EMISSIONS

TERAGRAMS/YEAR

SOURCE CATEGORY	1970	1971	1972	1973	1974	1975	1976	1977	1978
Transportation									
Highway vehicles	10.3	10.3	10.5	10.3	9.7	9.5	9.6	9.6	9.3
Aircraft	0.3	0.3	0.3	0.2	0.2	0.2	0.2	0.2	0.2
Railroads	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2
Vessels	0.4	0.4	0.4	0.4	0.4	0.4	0.5	0.5	0.5
Other motor vehicles	0.5	0.5	0.5	0.6	0.5	0.5	0.5	0.5	0.5
Transportation Total	11.7	11.7	11.9	11.7	11.0	10.8	11.0	11.0	10.7
Fuel combustion in Stationary sources	0.4	0.3	0.3	0.2	0.2	0.3	0.3	0.3	0.3
Industrial processes	11.2	11.1	12.1	12.6	12.2	11.1	12.2	12.6	13.6
Municipal incineration	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Other incineration	0.5	0.5	0.4	0.4	0.4	0.4	0.4	0.4	0.4
Open burning	1.3	0.9	0.8	0.7	0.6	0.5	0.5	0.5	0.4
Solid Waste Total	1.8	1.4	1.2	1.1	1.0	0.9	0.9	0.9	0.8
Miscellaneous									
Forest fires	0.5	0.8	0.5	0.5	0.6	0.4	0.7	0.5	0.5
Agricultural burning	0.3	0.2	0.1	0.1	0.1	0.1	0.1	0.1	0.1
Coal refuse burning	0.1	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Structural fires	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Misc. organic solvent	2.3	2.2	2.2	2.2	2.0	1.7	1.8	1.7	1.8
Miscellaneous Total	3.2	3.3	2.8	2.8	2.7	2.2	2.6	2.3	2.4
Grand Total	28.3	27.8	28.3	28.4	27.1	25.3	27.0	27.1	27.8

TABLE 6

NATIONAL ESTIMATES OF CARBON MONOXIDE EMISSIONS

TERAGRAMS/YEAR

SOURCE CATEGORY	1970	1971	1972	1973	1974	1975	1976	1977	1978
Transportation									
Highway vehicles	70.9	71.7	76.1	76.5	73.3	73.9	76.7	77.6	77.1
Aircraft	0.8	0.7	0.7	0.6	0.6	0.7	0.7	0.7	0.7
Railroads	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3
Vessels	1.2	1.3	1.4	1.4	1.4	1.4	1.5	1.5	1.5
Other motor vehicles	7.4	7.3	7.1	7.1	6.3	6.0	6.2	6.0	5.9
Transporation Total	80.6	81.3	85.6	85.9	81.9	82.3	85.4	86.1	85.5
Fuel combustion in stationary sources	1.5	1.4	1.3	1.3	1.3	1.3	1.2	1.2	1.2
Industrial processes	7.7	7.7	7.7	8.0	7.7	6.7	7.1	7.4	7.6
Solid waste disposal									
Muncipipal incineration	0.3	0.3	0.3	0.3	0.2	0.2	0.2	0.2	0.2
Other incineration	2.6	2.1	1.9	1.8	1.7	1.6	1.6	1.4	1.3
Open burning	3.6	2.7	2.1	1.8	1.5	1.4	1.3	1.3	1.2
Solid Waste Total	6.5	5.1	4.3	3.9	3.4	3.2	3.1	2.9	2.7
Miscellaneous									
Forest fires	4.3	5.9	4.3	3.5	4.5	3.0	5.4	4.1	4.3
Agricultural burning	1.5	1.2	0.8	0.6	0.5	0.5	0.5	0.5	0.5
Coal refuse burning	0.3	0.3	0.2	0.1	0.1	0.0	0.0	0.0	0.0
Structural fires	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.3
Misc. organic solvent	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Miscellaneous Total	6.3	7.6	5.5	4.4	5.3	3.7	6.1	4.8	5.1
Grand Total	102.6	103.1	104.4	103.5	99.6	97.2	102.9	102.4	102.1

TABLE 7

NITROGEN OXIDE EMISSIONS FROM HIGHWAY VEHICLES

GIGAGRAMS/YEAR

SOURCE CATEGORY	1970	1971	1972	1973	1974	1975	1976	1977	1978
Passenger cars	3,420	3,700	4,000	4,060	3,830	3,790	3,780	3,670	3,540
Light duty trucks	580	620	720	730	710	710	770	810	860
Heavy duty gasoline	510	570	700	750	700	740	850	900	890
Heavy duty diesel	820	860	940	970	1,080	1,110	1,210	1,340	1,390
Motorcycles	0	0	0	0	0	0	0	0	0
Total	5,300	5,800	6,300	6,500	6,400	6,400	6,600	6,800	6,700

Note: Total may differ slightly from sum of source category totals due to independent rounding of data.
One gigagram equals 10^9 grams (10^3 metric tons) or approximately 1.1×10^3 short tons.

TABLE 8

VOLATILE ORGANIC COMPOUND EMISSIONS FROM HIGHWAY VEHICLES

GIGAGRAMS/YEAR

SOURCE CATEGORY	1970	1971	1972	1973	1974	1975	1976	1977	1978
Passenger cars	7,800	7,700	7,650	7,460	6,920	6,740	6,530	6,330	5,970
Light duty trucks	1,230	1,220	1,360	1,330	1,290	1,270	1,380	1,420	1,470
Heavy duty gasoline	1,040	1,050	1,230	1,220	1,100	1,140	1,360	1,450	1,440
Heavy duty diesel	110	120	130	130	140	140	160	180	190
Motorcycles	90	130	150	170	200	200	200	200	190
Total	10,300	10,300	10,500	10,300	9,700	9,500	9,600	9.600	9,300

Note: Total may differ slightly from sum of source category totals due to independent rounding of data.
One gigagram equals 10^9 grams (10^3 metric tons) or approximately $1.1 \times 10_3$ short tons.

TABLE 9

CARBON MONOXIDE EMISSIONS FROM HIGHWAY VEHICLES

GIGAGRAMS/YEAR

SOURCE CATEGORY	1970	1971	1972	1973	1974	1975	1976	1977	1978
Passenger cars	51,400	51,800	53,000	53,400	51,300	51,500	51,000	50,600	49,700
Light duty trucks	7,180	7,240	8,350	8,400	8,520	8,530	9,640	10,100	10,700
Heavy duty gasoline	11,000	11,300	13,100	13,100	11,800	12,100	14,300	15,200	14,900
Heavy duty diesel	960	1,000	1,100	1,130	1,110	1,050	1,080	1,100	1,100
Motorcycles	280	420	480	550	630	630	640	640	610
Total	70,900	71,700	76,100	76,500	73,300	73,900	76,700	77,600	77,100

Note: Total may differ slightly from sum of source category totals due to independent rounding of data.
One gigagram equals 10^9 grams (10^3 metric tons) or approximately 1.1×10^3 short tons.

TABLE 10

PARTICULATE EMISSIONS FROM FUEL COMBUSTION IN STATIONARY SOURCES

GIGAGRAMS/YEAR

SOURCE CATEGORY	1970	1971	1972	1973	1974	1975	1976	1977	1978
Electric utilities									
Coal	3,990	3,830	3,920	4,230	3,690	3,540	3,100	3,290	2,350
Fuel oil	110	130	150	150	130	130	130	130	140
Natural gas	20	20	20	20	20	10	10	10	10
Utilities Total	4,120	3,980	4,090	4,400	3,840	3,680	3,240	3,430	2,500
Industrial									
Coal	2,140	1,710	1,570	1,340	1,080	740	700	790	700
Fuel oil	70	60	70	80	70	60	70	80	90
Natural gas	40	40	40	40	40	30	30	30	40
Other fuels	360	350	340	330	300	290	330	290	280
Industrial Total	2,610	2,160	2,020	1,790	1,490	1,120	1,130	1,190	1,110
Commercial									
Coal	190	150	150	120	120	50	50	30	20
Fuel oil	80	80	80	80	70	60	70	70	60
Natural gas	10	10	10	10	10	10	10	10	10
Commercial Total	280	240	240	210	200	120	130	110	90
Residential									
Coal	100	80	60	60	50	40	30	30	20
Fuel oil	20	20	20	20	20	20	20	20	20
Natural gas	30	30	30	30	30	30	30	30	30
Residential Total	150	130	110	110	100	90	80	80	70
Fuel Combustion Total	7,200	6,600	6,600	6,600	5,600	5,100	4,700	4,800	3,800

Note: Total may differ slightly from sum of source category totals due to independent rounding of data.
One gigagram equals 10^9 grams (10^3 metric tons) or approximately 1.1×10^3 short tons.

TABLE 11

SULFUR OXIDE EMISSIONS FROM FUEL COMBUSTION IN STATIONARY SOURCES

GIGAGRAMS/YEAR

SOURCE CATEGORY	1970	1971	1972	1973	1974	1975	1976	1977	1978
Electric utilities									
Coal	14,400	14,200	14,700	16,000	15,600	15,400	16,200	15,900	15,900
Fuel oil	1,480	1,480	1,440	1,630	1,520	1,440	1,630	1,650	1,720
Natural gas	0	0	0	0	0	0	0	0	0
Utilities Total	15,880	15,680	16,140	17,630	17,120	16,840	17,830	17,550	17,620
Industrial									
Coal	3,520	2,960	2,860	2,560	2,200	1,650	1,590	1,780	1,890
Fuel oil	930	860	950	1,020	990	780	1,010	1,150	1,150
Natural gas	0	0	0	0	0	0	0	0	0
Other fuels	150	150	150	150	150	150	150	150	150
Industrial Total	4,600	3,970	3,960	3,730	3,340	2,580	2,750	3,080	3,190
Commercial									
Coal	260	180	180	150	160	120	100	70	40
Fuel oil	1,220	1,170	1,200	1,180	1,060	890	990	990	
Natural gas	0	0	0	0	0	0	0	0	0
Residential Total	1,480	1,350	1,380	1,330	1,220	1,010	1,090	1,060	940
Residential									
Coal	380	270	210	200	160	120	100	80	60
Fuel oil	270	270	280	270	250	250	270	260	260
Natural gas	0	0	0	0	0	0	0	0	0
Residential Total	650	540	490	470	410	370	370	340	320
Fuel Combustion Total	22,700	21,600	22,100	23,200	22,100	20,900	22,200	22,200	22,100

Note: Total may differ slightly from sum of source category totals due to independent rounding of data.
One gigagram equals 10^9 (10^3 metric tons) or approximately 1.1×10^3 short tons.

TABLE 12

NITROGEN OXIDE EMISSIONS FROM FUEL COMBUSTION IN STATIONARY SOURCES

GIGAGRAMS/YEAR

SOURCE CATEGORY	1970	1971	1972	1973	1974	1975	1976	1977	1978
Electric Utilities									
Coal	3,430	3,530	3,790	4,200	4,200	4,270	4,820	5,100	5,120
Fuel oil	670	810	1,010	1,180	1,120	1,040	1,060	1,250	1,230
Natural gas	1,060	1,090	1,080	980	930	860	840	870	860
Utilities Total	5,160	5,430	5,880	6,360	6,250	6,170	6,720	7,220	7,210
Industrial									
Coal	900	760	730	680	650	540	530	600	610
Fuel oil	230	220	240	270	250	220	280	310	330
Natural gas	3,630	3,700	3,790	3,840	3,700	3,350	3,640	3,620	3,590
Other fuels	390	380	380	370	370	380	410	410	390
Industrial Total	5,150	5,060	5,140	5,160	4,970	4,490	4,860	4,940	4,920
Commercial									
Coal	40	30	30	30	30	20	20	10	10
Fuel oil	330	320	330	330	290	260	300	290	270
Natural gas	130	140	140	140	140	140	140	140	140
Commercial Total	500	490	500	500	460	420	460	440	420
Residential									
Coal	20	20	10	10	10	10	10	10	0
Fuel oil	140	150	160	150	140	130	150	140	140
Natural gas	210	210	220	210	200	210	210	220	210
Residential Total	370	380	390	370	350	350	370	370	350
Fuel Combustion Total	11,300	11,500	11,900	12,400	12,100	11,300	12,500	13,000	12,900

Note: Total may differ slightly from sum of source category totals due to independent rounding of data.
One gigagram equals 10^9 (10^3 metric tons) or approximately 1.1×10^3 short tons.

TABLE 13

PARTICULATE EMISSIONS FROM INDUSTRIAL PROCESSES

GIGAGRAMS/YEAR

SOURCE CATEGORY	1970	1971	1972	1973	1974	1975	1976	1977	1978
Iron and steel	1,360	1,200	1,230	1,390	1,250	950	940	780	830
Petroleum refineries	60	60	70	70	70	70	70	70	70
Primary Nonferrous Smelters	520	480	500	520	510	440	480	480	480
Cement	1,430	1,500	1,480	1,440	1,190	780	760	720	780
Fertilizers	60	50	50	40	40	40	40	40	40
Ferroalloys	140	130	130	110	90	60	60	50	50
Asphalt batching	440	460	460	370	280	190	130	140	150
Coal mines	120	130	130	130	150	160	170	180	180
Coal cleaning	200	110	80	60	40	30	30	10	10
Pulp paper	500	480	490	470	370	250	290	230	240
Iron foundries	200	210	200	190	190	120	130	140	140
Secondary Nonferrous metals	80	70	80	80	70	60	60	70	70
Crushed stone	3,150	2,940	2,800	2,880	2,750	1,880	1,550	1,430	1,340
Brick & clays	1,820	1,870	1,810	1,690	1,270	950	880	640	440
Lime	1,050	780	550	260	230	200	170	170	150
Other mineral products	340	340	340	340	310	240	260	280	280
Chemicals	200	160	150	150	150	130	150	150	150
Grain milling & storage	1,090	1,200	960	940	800	770	730	750	730
Miscellaneous	60	60	70	60	60	50	60	60	60
Total	12,300	12,300	11,600	11,200	9,800	7,400	7,000	6,400	6,200

Note: Total may differ slightly from sum of source category totals due to independent rounding of data.
One gigagram equals 10^9 (10^3 metric tons) or approximately 1.1 x 10^3 short tons.

TABLE 14

SULFUR OXIDE EMISSIONS FROM INDUSTRIAL PROCESSES

GIGAGRAMS/YEAR

SOURCE CATEGORY	1970	1971	1972	1973	1974	1975	1976	1977	1978
Natural gas production	100	100	120	150	160	160	130	120	140
Pulp & paper	60	70	70	70	70	70	80	80	80
Sulfuric acid	540	530	570	570	440	330	240	240	220
Petroleum refining	680	710	760	830	820	810	840	870	900
Glass	20	20	20	20	20	30	30	30	30
Cement	580	610	640	660	630	540	580	620	670
Coke production	150	130	140	150	140	130	140	130	110
Copper smelters	3,650	3,220	3,740	3,600	3,080	2,290	2,210	2,070	1,930
Lead & zinc smelters	420	360	310	170	170	170	180	90	30
Total	6,200	5,700	6,300	6,300	5,500	4,500	4,400	4,200	4,100

Note: Total may differ slightly from sum of source category totals due to independent rounding of data.
One gigagram equals 10^9 (10^3 metric tons) or approximately 1.1×10^3 short tons.

TABLE 15

NITROGEN OXIDE EMISSIONS FROM INDUSTRIAL PROCESSES

GIGAGRAMS/YEAR

SOURCE CATEGORY	1970	1971	1972	1973	1974	1975	1976	1977	1978
Organic chemicals	60	60	60	60	60	60	60	60	60
Ammonia	40	40	40	40	40	40	40	50	40
Nitric acid	160	160	190	150	150	130	140	130	130
Petroleum refining	320	310	340	360	360	350	360	380	390
Glass	40	40	40	40	40	50	50	50	60
Cement	90	90	100	100	90	80	90	90	100
Total	700	700	800	800	700	700	700	800	800

Note: Total may differ slightly from sum of source category totals due to independent rounding of data.
One gigagram equals 10^9 (10^3 metric tons) or approximately 1.1 x 10^3 short tons.

TABLE 16

VOLATILE ORGANIC COMPOUND EMISSIONS FROM INDUSTRIAL PROCESSES

GIGAGRAMS/YEAR

SOURCE CATEGORY	1970	1971	1972	1973	1974	1975	1976	1977	1978
Petroleum refineries	700	720	750	780	810	830	880	920	870
Petroleum product Storage & marketing	2,490	2,580	2,700	2,770	2,690	2,730	2,840	2,830	2,860
Organic chemicals	1,090	1,130	1,280	1,390	1,380	1,290	1,520	1,610	1,700
Plastics	180	190	230	260	270	220	280	310	340
Other chemicals	700	640	660	700	700	600	700	760	790
Surface coating	1,900	1,780	2,050	2,100	1,980	1,640	1,830	1,990	2,320
Degreasing	580	540	530	550	510	420	460	450	520
Graphic arts	290	280	320	320	300	260	290	300	350
Dry cleaning	280	260	300	300	280	250	270	270	320
Other organic solvent use	2,750	2,590	2,950	3,060	2,900	2,450	2,700	2,780	3,090
Miscellaneous	330	330	350	360	370	370	390	410	420
Total	11,200	11,100	12,100	12,600	12,200	11,100	12,200	12,600	13,600

Note: Total may differ slightly from sum of source category totals due to independent rounding of data.
One gigagram equals 10^9 (10^3 metric tons) or approximately 1.1×10^3 short tons.

TABLE 17

CARBON MONOXIDE EMISSIONS FROM INDUSTRY

GIGAGRAMS/YEAR

SOURCE CATEGORY	1970	1971	1972	1973	1974	1975	1976	1977	1978
Pulp & paper	530	540	590	600	600	550	630	630	660
Organic chemicals	330	340	400	440	410	380	450	480	540
Charcoal	70	70	80	80	90	90	100	100	100
Carbon black	2,500	2,250	2,050	2,170	1,990	1,700	1,880	2,180	2,200
Ammonia	100	100	110	110	110	120	120	130	120
Petroleum refining	2,050	2,140	2,150	2,240	2,210	2,260	2,250	2,260	2,270
Steel manufacturing	970	960	1,020	1,090	1,090	880	940	930	1,020
Coke production	50	50	50	50	50	50	50	40	40
Iron foundries	1,090	1,220	1,240	1,160	1,160	660	680	620	610
Total	7,700	7,700	7,700	8,000	7,700	6,700	7,100	7,400	7,600

Note: Total may differ slightly from sum of source category totals due to independent rounding of data.
One gigagram equals 10^9 (10^3 metric tons) or approximately 1.1 x 10^3 short tons.

3. METHODS

The generation of an emission inventory involves many steps to achieve the desired result, which is to estimate the amount of emissions for selected pollutants in a defined geographical area. Ideally, nationwide emission estimates should result from a summation of county, state, and regional data in which each component is reported separately. The National Emissions Data System (NEDS) uses this procedure. The methods used to prepare data for this publication are as similar as possible to those used for NEDS data preparation. Since NEDS uses a more detailed procedure involving calculation of emissions for individual sources and summation of these individual emission totals to produce national totals, there is a much greater chance for errors or omissions to occur in the NEDS data. Because of the basic similarity of techniques, discrepancies between national totals reported herein and those given in NEDS reports are due largely to incomplete data reporting and errors in the NEDS data. In time, it is anticipated that the quality of NEDS data will improve so that the differences between future NEDS emission reports and national emission totals determined by the procedure used for this publication will be minimal.

Because it is impossible to test every pollutant source individually, particularly area sources, an estimating procedure must be used. In order to do this, however, one must either estimate the emissions directly or estimate the magnitude of other variables that can then be related to emissions. These indicators include fuel consumption, vehicle miles, population, sales, tons of refuse burned, raw materials processed, etc., which are then multiplied by appropriate emission factors to obtain emission estimates.

The limitations and applicability of emission factors must be understood. In general, emission factors are not precise indicators of emissions from a single source; rather, they are quantitative estimates of the average rate of pollutant released as a result of some activity. They are most valid when applied to a large number of sources and processes. If their limitations are recognized, emission factors are extremely useful in determining emission levels. A detailed discussion of emission factors and related information is contained in Reference 2. The emission factor thus relates quantity of pollutants emitted to indicators such as those noted above, and is a practical approach for determining estimates of emissions from various source categories.

A discussion of trends is meaningful only when there is a common basis for evaluation. It was necessary, therefore, to quantify emissions using the same criteria for each year. This meant using the same estimation techniques, using equal or equivalent data sources, covering the same pollutant sources, and using compatible estimates of pollutant control levels from year to year. Estimates for previous years were updated using current emission factors and including the most recent information available. The criteria used in calculating emissions was the same for all years.

The methodology used in generation of emission estimates for individual source categories follows.

3.1 Transportation

3.1.1 Motor Vehicles

Emission estimates from gasoline-and diesel-powered motor vehicles were based upon vehicle-mile tabulations and emission factors. Four vehicle categories are considered; light duty gasoline (mostly passenger cars), light duty trucks (trucks less than 8500 pounds in weight), heavy duty gasoline trucks and buses, and heavy duty diesel trucks and buses. The emission factors used are based on the latest available data from Reference 3. The MOBILE 1 model, developed by the EPA Office of Transportation and Land Use Policy was used to calculate emission factors. The factors are based on national average conditions and do not include corrections for specific geographical areas to account for local model year distributions, altitude, temperature, or hot/cold vehicle operation differences. For each of these variables, only national averages were considered in the emission factors. Average speed is taken into account on a nationwide basis according to the published distribution of vehicle-miles travelled (VMT) for urban and rural fractions. These data are published in Reference 4. For rural VMT, the average speed is considered to be 45 miles per hour, and for urban VMT, 19.6 miles per hour.

3.1.2 Aircraft

Aircraft emissions are based on emission factors and aircraft activity statistics reported by the Federal Aviation Administration.[5] Emissions are based on the number of landing-takeoff (LTO) cycles. Any emissions in cruise mode,

which is defined to be above 3000 feet (1000 meters) are ignored. Average emission factors, which take into account the national mix of aircraft types for general aviation, military, and commercial aircraft, are used to compute the emissions.

3.1.3 Railroads

The Department of Energy reports consumption of diesel fuel and residual fuel oil by railroads.[6] Average emission factors applicable to diesel fuel consumption were used to calculate emissions. The average sulfur content of each fuel was used to estimate SO_x emissions.

3.1.4. Vessels

Vessel use of diesel fuel, residual oil, and coal is reported by the Department of Energy.[6,7] Gasoline use is based on national boat and motor registrations, coupled with a use factor (gallons/motor/year) from Reference 8. Emission factors from AP-42[2] are used to compute emissions. Since AP-42 does not contain an emission factor for coal use by vessels, an average emission factor for coal combustion in boilers was used.

3.1.5 Nonhighway Use of Motor Fuels

Gasoline and diesel fuel are consumed by off-highway vehicles. The fuel use is divided into seven categories; farm tractors, other farm machinery, construction equipment, industrial machinery, small general utility engines such as lawnmowers and snowthrowers, snowmobiles, and motorcycles. Fuel use is estimated for each category from estimated equipment population and an annual use factor of gallons per unit per year.[8]

3.2 Fuel Combustion in Stationary Sources

3.2.1 Coal

Bituminous coal, lignite, and anthracite coal use are reported by the Department of Energy.[7] Most coal is consumed by electric utilities. Average emission factors and the sulfur content of each type of coal were used to estimate emissions. Degree of particulate control was based on a report by Midwest Research Institute[9] together with data from NEDS[10] and the Compliance Data System (CDS).[11]

3.2.2 Fuel Oil

Distillate oil, residual oil, and kerosene are consumed by stationary sources nationwide. Consumption by user category is reported by the Department of Energy.[6] Average emission factors and the sulfur content of each fuel were used to estimate emissions.

3.2.3 Natural Gas

Natural gas consumption data are also reported by the Department of Energy.[12] Liquefied petroleum gas (LPG) use is also included with natural gas for the purpose of estimating emissions. Average emission factors from AP-42[2] were used to calculate the emission estimates.

3.2.4 Other Fuels

Consumption of wood, process gas, and bagasse is based on data reported in NEDS.[10] Average emission factors were used to calculate emissions, which are relatively minor on a national basis.

3.3 Industrial Processes

In addition to fuel combustion, certain other industrial processes generate and emit varying quantities of pollutants into the air. The lack of published national data on production, type of equipment, and controls, as well as an absence of emission factors, makes it impossible to include estimates of emissions from all industrial process sources.

Production data for industries that are known to produce the great majority of emissions were derived from literature data. Generally, the Minerals Yearbook,[13] published by the Bureau of Mines, and Current Industrial Reports,[14] published by the Bureau of the Census, provide adequate data for most industries. Average emission factors were applied to production data to obtain emissions. Control efficiencies applicable to various processes were estimated on the basis of published reports,[9] from NEDS data,[10] or from CDS data.[11]

For the purposes of this report, petroleum product storage and marketing operations (gasoline, crude oil, and distillate fuel oil storage and transfer, gasoline bulk terminals and bulk plants, retail gasoline service stations) are included as industrial processes. Also included as industrial processes are industrial surface coating and degreasing operations, graphic arts (printing and publishing), and dry cleaning operations. All of these processes involve the use of organic solvents.

For the purposes of this report, the storage, transportation, and marketing of petroleum products are also included as industrial processes. Emissions of volatile organic compounds from this source category as well as VOC emissions from selected other industrial process categories are based on the national emission estimates given in Reference 15, which were adjusted according to relative production levels for each year to derive the emission estimates presented in this report.

3.4 Solid Waste Disposal

A study conducted in 1968 on solid waste collection and disposal practices[16] was the basis for estimating emissions from solid waste disposal. Results of this study indicate that the average collection rate of solid waste is about 5.5 pounds per capita per day in the United States. It has been stated that a conservative estimate of the total generation rate is 10 pounds per capita per day. The results of this survey were updated and used to estimate, by disposal method, the quantities of solid waste generated. Average emission factors were applied to these totals to obtain estimates of total emissions from the disposal of solid wastes.

3.5 Miscellaneous Sources

3.5.1 Forest Fires

The Forest Service of the Department of Agriculture publishes information on the number of forest fires and the acreage burned.[17] Estimates of the amount of material burned per acre are made to estimate the total amount of material burned. Similiar estimates are made to account for managed burning of forest areas. Average emission factors were applied to the quantities of materials burned to calculate emissions.

3.5.2 Agricultural Burning

A study[18] was conducted by EPA to obtain from local agricultural and pollution control agencies estimates of the number of acres and estimated quantity of material burned per acre in agricultural burning operations. These data have been updated and used to estimate agricultural burning emissions, based on average emission factors.

3.5.3 Coal Refuse

Estimates of the number of burning coal-refuse piles existing in the United States are made in reports by the Bureau of Mines.[19] Their publication presents a detailed discussion of the nature, origin, and extent of this source of pollution. Rough estimates of the quantity of emissions were obtained using this information by applying average emission factors for coal combustion. It was assumed that the number of burning refuse piles decreased to a negligible amount by 1975.

3.5.4 Structural Fires

The United States Department of Commerce publishes, in their statistical abstracts, information on the number and types of structures damaged by fire[20]. Emissions were estimated by applying average emission factors for wood combustion to these totals.

3.5.5 Nonindustrial Organic Solvent Use

This category includes trade sales of surface coatings (primarily for architectural coating) solvent evaporation from consumer products (aerosols, space deodorants, polishes, toiletries, etc.), use of volatile organic compounds as general cleaning solvents, paint removers, and liquefaction of asphalt paving compounds, and other undefined end uses. Total national organic solvent use is estimated from chemical production reports of the U.S. Tariff Commission[21], together with estimates of the portion of total production for use as solvent for each chemical.[22] It is assumed that all solvent production is equal to the amount necessary to make up for solvent lost through evaporation. Estimated emissions from organic solvent use by industrial processes and selected nonindustrial solvent use categories were obtained from Reference 15. Solvent use not accounted for by industrial processes is reported as nonindustrial organic solvent use, with annual estimates adjusted according to solvent production levels.

4. Analysis of Trends

National trends in air pollutant emissions are a function of a number of factors. Air pollution control measures and economic conditions have the strongest impact on total emissions. National emission trends do not provide any insight into the distribution or concentration of air pollution sources within the United States. Therefore, local emission trends do not necessarily coincide with national emission trends. Based on the national implementation of control measures for some classes of sources, such as highway motor vehicles, it is reasonable to infer that for most localities, the national trend in emissions reasonably approximates local trends in emissions for the same class of sources.

In addition to the fact that national emission trends do not measure local changes in emission densities, national emission trends may not be consistent with air quality trends because of the impact of meteorological factors on air quality data. Also, the estimates for TSP, SOx, and NOx emissions include more substances than are routinely measured by ambient air monitoring equipment. For example, high-volume air samplers collect only suspended particulates approximately 0.3 to 100 micro-meters in diameter, but TSP emission inventories include both suspended and settled particulates generated by man's activities. Likewise sulfur dioxide (SO_2) and nitrogen dioxide (NO_2) ambient air monitors measure only those two compounds while oxides of sulfur (SOx) and nitrogen (NOx) are included in the emission estimates. In each case, the substance measured by the ambient air monitor is the most prevalent constitutent of its pollutant class or is acknowledged to be its most representative indicator. Estimates of oxidant emissions are not provided because most oxidant species are secondary pollutants generated by photochemical reactions in the atmosphere. Emission estimates of VOC, a major ingredient in oxidant-producing reactions, were developed from current emission factors.[2,3] Generally, excluded from VOC estimates were emissions of methane, ethane, methyl chloroform, and Freon 113, which are considered to be of negligible photochemical reactivity. Organic species were identified based on Reference 24. If no data were available for a source category, the total hydrocarbon emission factor from Reference 2 was used. Highway vehicle emissions were estimated as nonmethane VOC's.[3]

The following sections discuss the most important factors influencing the emission trends for each pollutant.

TABLE 18

THEORECTICAL 1978 NATIONAL EMISSION ESTIMATES
BASED ON 1970 LEVEL OF CONTROL

TERAGRAMS/YEAR

Source Category	TSP	SOX	NOX	VOC	CO
Transportation					
Highway vehicles	1.0	0.4	7.5	14.6	101.9
Non-Highway	0.4	0.4	2.7	1.5	8.4
Transportation Total	1.4	0.8	10.2	16.1	110.3
Fuel Combustion					
Stationary sources					
Electric utlities	7.2	24.1	7.2	0.1	0.3
Industrial	2.0	3.8	4.9	0.2	0.6
Commercial	0.1	1.2	0.4	0.0	0.1
Residential	0.1	0.3	0.4	0.0	0.2
Fuel Combustion Total	9.4	29.4	12.9	0.3	1.2
Industrial Processes					
Chemical	0.2	0.7	0.3	2.8	3.0
Petroleum refining	0.1	1.1	0.4	0.9	2.4
Mineral products	10.1	0.7	0.1	0.1	0.0
Metals	2.8	3.5	0.0	0.0	2.3
Other processes	2.2	0.4	0.0	9.9	0.7
Industrial Processes Total	15.4	6.4	0.8	13.7	8.4
Solid waste	1.1	0.1	0.3	1.8	6.5
Miscellaneous	1.0	0.1	0.2	2.7	6.4
Total	28.3	36.8	24.4	34.6	132.8
1978 Actual Emissions (Table 1)	12.5	27.0	23.3	27.8	102.1
Theoretical 1978 Emissions As A Percentage of 1978 Actual Emissions	226%	136%	105%	124%	130%
1970 Actual Emissions (Table 1)	23.2	29.8	19.9	28.3	102.6
Theoretical 1978 Emissions As A Percentage of 1970 Actual Emissions	122%	123%	123%	122%	129%

4.1 Particulates

Particulate emissions result primarily from fuel combustion in stationary sources and from industrial processes. Substantial reductions in particulate emissions have occurred because of the installation of control equipment on these sources. The extent of the reduction is most evident from the data in Table 18 which shows theoretical 1978 national emission estimates, assuming that pollutant control levels did not change since 1970. Overall, particulate emissions would have increased by about 22 percent if the extent of particulate control had not increased. In reality, as shown in Table 1, particulate emissions decreased about 46 percent. Thus, 1978 actual particulate emissions were less than half of what they would have been without control efforts.

More specifically, with no change in the level of control, emissions from fuel combustion in stationary sources would have increased from 7.2 teragrams to 9.4 teragrams, a 30 percent increase. In fact, particulate emissions decreased to 3.8 teragrams, a 47 percent decrease. The electric utility sector has the largest potential for particulate emissions. This is due to the extensive use of coal-fired boilers to generate electricity. In 1970, electric utilities consumed approximately 317 million tons of coal.[23] By 1978, this total had increased to about 470 million tons.[23] Despite this extensive increase in coal consumption, particulate emissions from electric utilities decreased 39 percent. Improvement or installation of control equipment on existing sources and New Source Performance Standards (NSPS) requirements for new facilities can be credited with the achievement of this emission reduction. Particulate emissions from other stationary fuel combustion sectors have also decreased. Additional control equipment has been installed on industrial and commercial coal-fired boilers. In addition, the actual consumption of coal by these and the residential sector declined from 1970 to 1978.

Particulate emissions from industrial processes also decreased because of installation of additional controls. As noted in the tables, with no change in the level of control, increases in industrial production would have caused a slight increase in emissions from 12.8 to 15.4 teragrams. In fact, industrial process particulate emissions decreased 52 percent to 6.2 teragrams. Substantial reductions were achieved in mineral products (cement, crushed stone, brick, lime, etc.) and primary metal industries, most notably in iron and steel production.

A caveat that should be noted with respect to these particulate emission estimates is that fugitive particulate (emissions from unconfined sources such as storage piles, material loading, etc.) emissions are incompletely accounted for in the emission totals. Rough estimates of industrial process fugitive emissions are included for some industries. Area source fugitive dust emissions (unpaved roads, construction activities, etc.) are not included at all. Similarly, natural sources of particulates, such as wind erosion or dust, are not included. (An exception is forest fires, some of which result from natural causes). In total, these fugitive emissions may amount to a considerable portion of total particulate emissions. The controls applied to these sources have so far been minimal. Due to the lack of adequate emission factors and emission inventory techniques for these sources, fugitive particulate emissions have not been included in most emission inventories. As additional data become available, it is expected that estimates of fugitive particulate emissions will be included in future reports.

4.2 Sulfur oxides

Fuel combustion by stationary sources produces most sulfur oxide emissions. In addition, certain industrial processes, such as smelting of copper, lead, and zinc ores, sulfuric acid manufacturing, and other industries also produce sulfur oxide emissions. Significant emission reductions from industrial processes have occurred, mostly from non-ferrous smelters and sulfuric acid plants. By-product recovery of sulfuric acid at smelters has increased since 1970. As a result sulfur oxide emissions that previously would have been released to the atmosphere are recovered as sulfuric acid. Since 1972 new sulfuric acid manufacturing plants have been subject to New Source Performance Standards requirements. These rules have contributed to decreased emissions as new plants built to meet new product demands or replace old facilities must meet more stringent emission limitations than old facilities.

As shown in the tables, sulfur oxide emissions from electric utilities account for more than half of total emissions. Combustion of sulfur-bearing fuels, chiefly coal and residual fuel oil, is responsible. Between 1970 and 1978 utility use of coal increased about 50 percent and residual oil use increased about 75 percent.[23] Emissions from utilities have increased only slightly, because fuels with lower sulfur content have been used to the extent that they were available. Flue gas desulfurization systems have seen only limited use to date and these have not had a major impact on emissions. The theoretical 1978 National emission estimates given in Table 18 for stationary fuel combustion sources are based on 1978 fuel amounts but 1970 average sulfur contents. On this basis, electric utility emissions would have increased 52 percent. In fact, emissions increased only 11 percent. Sulfur oxide emissions from other fuel combustion sectors decreased, primarily due to less coal burning by these consumers.

4.3 Nitrogen oxides

Nitrogen oxide emissions result almost entirely from transportation and stationary fuel combustion sources. Only limited controls have been applied to sources of NOx emissions. Table 18 shows that with the 1970 control level, national NOx emissions would have been only 5 percent higher than actual 1978 emissions. The emissions from stationary fuel combustion sources reflect the actual growth in fuel consumption. For mobile sources, NOx emissions were controlled as a result of the Federal Motor Vehicle Control Program (FMVCP). Nitrogen oxide emissions from highway vehicles would have increased 42 percent, had there been no change in control level since 1970. The estimates of actual NOx emissions show a 26 percent increase.

4.4 Volatile organic compounds

Emissions of VOC decreased primarily due to motor vehicle controls and less burning of solid waste. Had controls not been implemented, a substantial increase in emissions from highway vehicles would have occurred. From 1970 to 1978 vehicle-miles of travel in the U.S. increased by about 37 percent.[4] A comparable increase in emissions would have occurred had 1970 control levels remained unchanged. As a result of the controls put in place, VOC emissions from highway vehicles actually decreased 10 percent. VOC emissions also decreased due to the substitution of water-based emulsified asphalts (used for road paving) for asphalts liquefied with petroluem distillates (cutback asphalts). This is reflected in the decreased emissions reported for miscellaneous organic solvent use.

These decreases were offset by increases in industrial process emissions so that overall, total VOC emissions were reduced only slightly. Emissions from petroleum refining and chemical production increased due to expanded production of organic chemicals and petroleum products. Emissions from petroleum product storage and marketing also increased due to increase demand for gasoline and other petroleum products.

4.5 Carbon monoxide

Carbon monoxide emissions occur mainly from highway vehicles. From 1970 through 1973, emissions from highway vehicles increased. In 1974, CO emissions decreased and subsequently have increased again through 1978. Overall, from 1970 to 1978, highway vehicle emissions increased 9 percent. This trend is the result of the competing forces of growth in motor vehicle-miles travelled (VMT) and controls to limit CO emissions from motor vehicles. From 1970 through 1972, controls had a limited effect in reducing emissions.

In 1973, the control measures had achieved enough impact to approximately balance the growth in VMT. In 1974, emissions decreased as total VMT also decreased as the result of a shortage of motor fuel. From 1975 through 1977, VMT increased again, such that the net effect of VMT growth and motor vehicle controls was an increase in CO emissions. In 1978, CO emissions decreased slightly from 1977 levels. It should be noted that this analysis is based on existing emission factors computed from the EPA MOBILE 1 model[3]. Emission factors for post-1975 model years are projected rather than based on actual tests of in-use vehicles. Actual in-use emission rates for post-1975 vehicles may be higher than the projected values. If no controls other than those in place in 1970 had been implemented, highway vehicle emissions would have increased 44 percent from 1970 to 1978. This is substantially higher than the estimated 9 percent increase in actual emissions.

CO emissions from other sources either decreased or remained about the same from 1970 to 1978. The most sizeable reductions resulted from decreased burning of solid waste and agricultural materials. These decreases approximately balanced the increase in emissions from highway vehicles so that in 1978 total CO emissions were almost identical to the 1970 total.

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